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# COMPARISON OF NOAA/NMC STRATOSPHERIC WIND ANALYSES WITH UARS HIGH RESOLUTION DOPPLER IMAGER WIND MEASUREMENTS

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Abstract The NOAA National Weather Service currently derives global stratospheric wind analyses via several procedures. The first is the operational data assimilation system that extends from the surface up to about 50 mb and is in process of being tested to about 10 mb. In addition, a balanced wind is determined from the available Climate Analysis Center stratospheric height analyses that encompass the 70-0.4 mb region. The High Resolution Doppler Imager (HRDI) recently launched as a member of the Upper Atmosphere Research Satellite (UARS) is the first satellite instrument designed to measure winds in this stratospheric region and, thus, provide a basic evaluation of the NMC derived products. The HRDI accomplishes this by utilizing a triple-etalon Fabry-Perot interferometer that allows one to measure the Doppler shift of $O_2$ absorption and emission features of the atmosphere, from which the wind field can be determined.

In this paper we will discuss, very briefly, the basic attributes of the analyses and wind measurement systems and present the first comparisons of the two.

## I. Introduction

The High Resolution Doppler Imager (HRDI) is the primary instrument for measuring the dynamics of the stratosphere on-board the NASA Upper Atmosphere Research Satellite launched in September 1991. The goal of the HRDI is to measure wind velocities in the stratosphere and mesosphere during the day and the mesosphere and lower thermosphere at night to an accuracy of 5 $ms^{-1}$. Winds in the stratosphere are determined by measuring Doppler shifts of $O_2$ atmospheric band absorption features between 600-700 nm (Hays, 1982) utilizing a triple-etalon Fabry-Perot interferometer. Absorption features are observed in sunlight scattered into the field of view by aerosols and molecules, as the instrument scans the limb of the earth from cloud tops to stratospheric altitudes (Hays et al, 1992). By pointing to the same air parcel from two different directions as the satellite moves along its orbit, the vector wind is determined. Typically, the time difference between successive measurements of a common volume is approximately 9 minutes. More specific details of the HRDI instrument and method of operation are provided by Hays et al (1992). At this time, the algorithm for wind determination appears to be very much influenced by the underlying cloud scene, such that for this examination we will focus attention on information near or above about 30 km.

At the above levels, the National Meteorological Center, currently produces only one series of daily global analyses of temperature and height, that provided by the Climate Analysis Center at the pressure levels of 70-, 50-, 30-, 10-, 5-, 2-, 1- and 0.4-mb or about 18, 22, 25, 30, 35, 40, 48 and 55 km, respectively. This analysis system is not based on a forecast model data assimilation scheme, but on an iterative adjustment process from the first guess (Gelman et al, 1986). Observed winds from rawinsondes are only included in a very loose fashion within the final iterations. Up to 10- mb, the data employed within the analysis system are a combination of rawinsonde and NOAA operational satellite information (TIROS Operational Vertical Sounder system on-board the NOAA satellite series) in the Northern Hemisphere. In the Southern Hemisphere and at all pressure levels above 10-mb, only the satellite data are utilized. Global winds, in this system are derived from the height field either using the geostrophic approximation or a balanced wind procedure (e.g. Randel, 1987).

## II. Data

For this first comparison of the HRDI and NMC data, we focus on one day, December 23, 1991, 1200 UTC. In the case of the standard weather products, we will depict wind fields determined from two sources. For the first, we simply present the rawinsonde data available for the above map time. The second is that computed from the standard height fields from the balance wind approximation with the time tendency and vertical advection terms excluded (Randel, 1987). The equations are presented below.

$$2\Omega\sin\phi\cdot v = \frac{1}{a\cos\phi}\frac{\partial\Phi}{\partial\lambda} + \left[\frac{u}{a\cos\phi}\frac{\partial u}{\partial\lambda} + \frac{v}{a\cos\phi}\frac{\partial}{\partial\phi}(u\cos\phi)\right]$$

$$2\Omega\sin\phi\cdot u = -\frac{1}{a}\frac{\partial\Phi}{\partial\phi} - \left[\frac{v}{a}\frac{\partial v}{\partial\phi} + \frac{u^2}{a}\tan\phi + \frac{u}{a\cos\phi}\frac{\partial v}{\partial\lambda}\right]$$

where u is the zonal wind, v the meridional wind and the other terms follow the standard meteorological convention.

In this case the wind fields are first determined geostrophically, and then the above equations are solved via 5 iterations (Randel, 1987). The biggest difference, in general, from geostrophy occurs when the curvature is greatest, but for this particular data depiction (which is based on the locations of HRDI data points) the results are so similar that we present only those based on the balanced wind.

For the HRDI data, the information presented are screened according to two guidelines. The satellite observation must be within +/- 6 hours of the above map time, and the determined wind value must be greater than the error bar associated with that value; that is the data must have a signal to noise ratio greater than one.

Due to current constraints on the HRDI algorithm, concerns have been raised on the determined values in the lower stratosphere and we will focus attention on the 30 km level and compare that with the observations on 10 mb.

## III. Results

Figure 1 shows the 10 mb height map for December 23, 1991 and we see that the pattern is dominated by the polar low (center value 28.3 geopotential kilometers with a major ridge (center value 31.3 geopotential kilometers) over the North Pacific and several minor ridges over Europe and Asia. As the geopotential surfaces (which are an energy level) are within about 200 meters of the geometric heights at this altitude, we see that we are, generally, within 2 km of the HRDI 30-km level data.

In Figure 2 we present the observed rawinsonde winds at 1200 UTC for this day. The mid-point of the wind vectors are the locations of the values. We see that the available data, which is much reduced in numbers compared to the lower levels, show the generally high latitude westerlies and the ridge structure over the North Pacific and Eastern Asia, but are insufficient to depict that over Northern India. In fact, the 0000 UTC rawinsondes depicted in Figure 3 indicate that the winds in this area are somewhat transient. Elsewhere, the results from 0000 and 1200 UTC are quite similar save for the one wind over the southwest United States at 0000 UTC which appears somewhat large compared to the others.

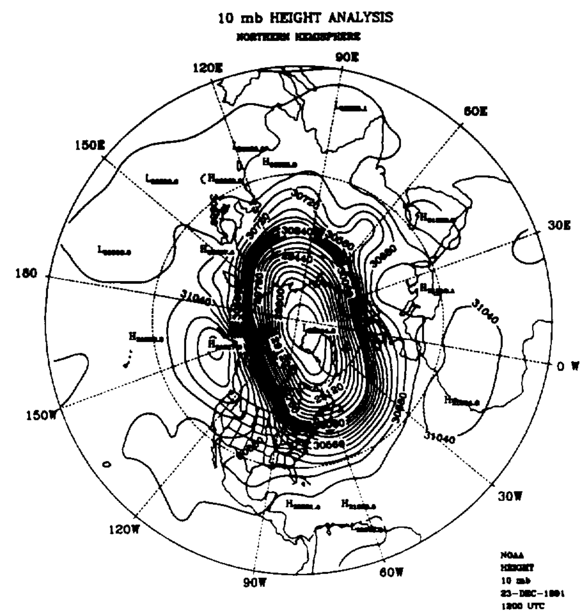


Figure 1. NMC 10-mb height analysis for December 23, 1991, 1200 UTC. Units: geopotential meters.

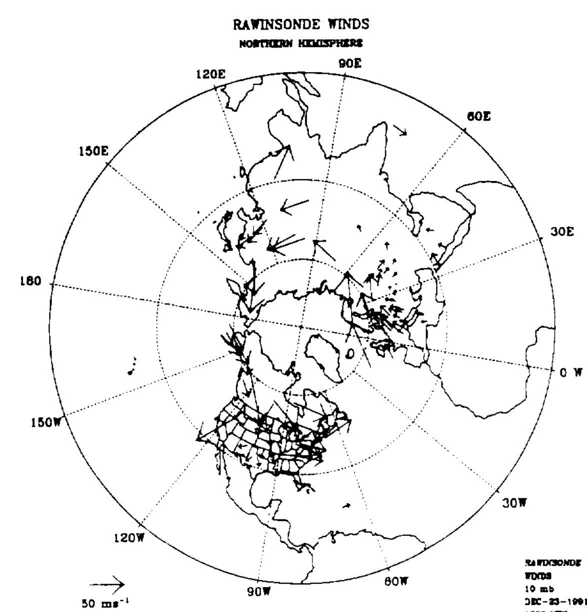


Figure 2. 10-mb observed 1200 UTC rawinsonde winds for December 23, 1991. Units: $ms^{-1}$.

Figure 4 depicts the results of the balanced wind calculation. For this figure we present only those values interpolated to the same locations of the HRDI data that pass the screening procedure outlined above. We see that the comparisons are made somewhat difficult by the fact that the rawinsonde observation locations do not tend to coincide with those of the HRDI data. The general picture, however, is that both show the major polar trough and the European ridge. The situation over Asia is less clear.

Finally, then, Figure 5 shows the HRDI results. We should recall that the stratospheric winds are dependent on available sunlight for the wind measurement and that limitation restricts the latitudinal coverage for this particular day. As the sun progresses poleward, so too do the measurements. Also, we have screened the data quite severely for this initial comparison. Together, then, the data quantity is limited. For the HRDI data we see that the overall depiction is in quite good agreement with the other data sets, although differences show up most noticeably over Europe and Asia. In particular, the data over Europe show a very strong convergence at about 20E not indicated in the other data. Over Asia, the HRDI data differ from the others, but as we have seen above, the true situation is not clear.

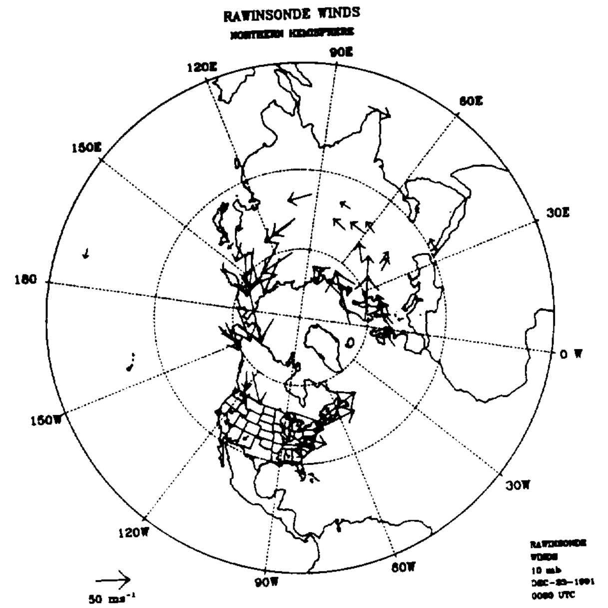


Figure 3. 10-mb observed 0000 UTC rawinsonde winds for December 23, 1991. Units: $ms^{-1}$.

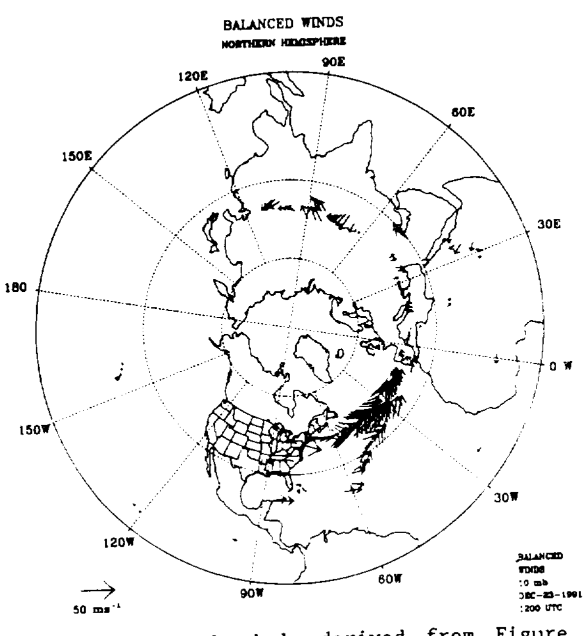


Figure 4. Balanced winds derived from Figure 1 height field. Units: $ms^{-1}$.

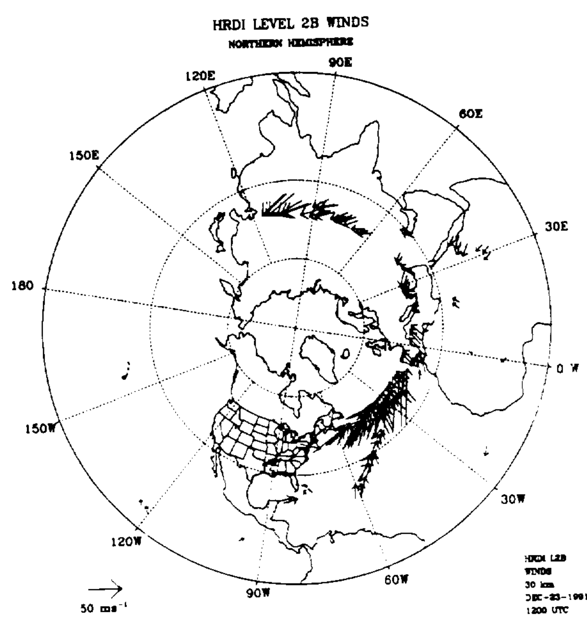


Figure 5. HRDI 30 km observed winds for 1200 UTC December 23, 1991. Units: $ms^{-1}$.

IV. Summary

Although the HRDI data are still in an early stage of their algorithm evaluation and development, we see that their potential is vast. At 10 mb, for example, the available rawinsonde data in the Northern Hemisphere are very few and mainly restricted to the major land areas. The HRDI information provide our first possibility to fill-in this important data set over the globe and help define the horizontal winds and transport mechanisms in the stratosphere.

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